

**New York State Department of Transportation
STRUCTURES DIVISION**

STRUCTURES DESIGN ADVISORY

**Issued by:
MAIN OFFICE
STRUCTURES
DIVISION**

**SUBJECT: FRP Decks
&
Superstructures**

**CODE: 02-003

DATE: Dec. 9, 2002**

APPROVED BY:

**SUPERSEDES:
None**

I. PURPOSE:

The purpose of this advisory is to provide guidance on the application of fiber reinforced polymer (FRP) composites for bridge decks and superstructures. These materials are a new technology in bridge applications and in the right circumstances can offer significant advantages over traditional materials. This design advisory offers guidance for their use.

II. BACKGROUND:

FRP composite decks and superstructures have been used on eight bridges in New York State and approximately 40 nationwide. Though composites have been researched and used extensively in other industries, these bridge projects were designed and built without the benefit of nationally accepted standards. This document is based on recent construction experience of various DOT's, input from researchers, general state of the art, and in-service performance.

FRP bridge decks and superstructures are typically made with vinylester or polyester resin reinforced with E-glass fiber. They are pre-engineered and fabricated in a shop, then assembled and installed at a bridge site where a wearing surface is added. FRP's are engineered materials with their strength dependant on several factors such as fiber type, fiber volume, fiber orientation, resin type, manufacturing method, and the bonding materials used in the final assembly.

Advantages and disadvantages of FRP decks and superstructures are summarized below.

Advantages:

1. Light weight. A typical 200mm (8") FRP deck with its wearing surface weighs approximately 122 kg/m² (25 psf) vs. 581 kg/m² (119 psf) for a standard 240mm (9.5") concrete deck.

STRUCTURES DESIGN ADVISORY CODE: 02-003	DATE: Dec. 9, 2002	PAGE: 3
SUBJECT: FRP Decks & Superstructures		

A typical new superstructure composed completely of FRP materials and spanning 10m (30') weighs approximately 270 kg/m² (55psf).

2. Resistance to de-icing salts and other chemicals.
3. Fast installation due to modular, pre-fab nature and the elimination of time consuming forming and curing necessary for conventional concrete decks.
4. Reduced traffic delay which leads to lower user costs, less expense for maintenance and protection of traffic, and better public relations.
5. Good durability. The cracking, corrosion of reinforcement, and spalling associated with concrete decks is eliminated.
6. Long service life. Many large, non-civil structures have been used in harsh environments for decades. FRP decks are expected to provide a long service life with little maintenance. While definitive estimates of the service life of an FRP deck cannot be made at this time, it is not unreasonable to expect the service life of the FRP deck to be as long as the bridge.
7. Fatigue resistance.
8. Fabrication in a controlled environment is conducive to good quality control.
9. Ease of installation. A deck replacement project can be done with a stand-by "where & when" contractor or maintenance forces using standard details. This type of project administration can bring fast relief of a posting problem.
10. A bridge rehabilitation using FRP can solve a posting problem for much less than a bridge replacement.
11. Less environmental impact and fewer permits will be required if a bridge can be rehabilitated through the use of lightweight FRP than replaced.

Disadvantages:

1. Higher initial cost compared to a conventional concrete deck. The unit cost of FRP materials is often more expensive than conventional materials.
2. FRP's low modulus of elasticity leads to a deflection driven design which does not allow a designer to fully capitalize on the FRP's strength.
3. Currently available designs are proprietary. There is no standard manufacturing process.
4. Response to thermal change is slightly different than for concrete and steel and requires special consideration when an FRP deck is used on a concrete or steel superstructure or when FRP is used for a superstructure.
5. Some past projects have experienced a failure of the wearing surface (i.e. cracking and/or debonding). Research is underway to identify the best material for a wearing surface.
6. A thorough analysis of the material's behavior requires a finite element model. This will be a requirement for approval of the system.

STRUCTURES DESIGN ADVISORY CODE: 02-003	DATE: Dec. 9, 2002	PAGE: 4
SUBJECT: FRP Decks & Superstructures		

7. FRP material properties like strength and stiffness naturally degrade over time. The resultant tendency to creep must be addressed in the design. Appropriate strength reduction factors need to be used to insure adequate stiffness over the entire service life of the structure.
8. Limited FRP experience within the construction industry.
9. Lack of long term performance data. There are few FRP bridges that have been in service for any substantial length of time. The first bridge in the U.S. to carry public traffic was built in 1997. New York's first FRP bridge opened a year later.
10. Lack of design standards and conventions for material characterization.
11. Bridge railing systems attached to FRP decks have not been crash tested. Static tests have been done successfully.

There are several active research projects that will further the state of the practice. NYSDOT is assessing various types of wearing surfaces to find a durable one that bonds well to FRP. Federal Highway Administration has contracted for studies that may evolve into AASHTO guidelines for the design and construction of composite decks and superstructures, as well as for material standards. In addition, FHWA's Innovative Bridge Research and Construction (IBRC) funding program will provide an abundance of data from completed projects.

There are several manufacturing methods used for FRP decks. (*pultrusion* e.g. Martin Marietta Composites, *vacuum-assisted-resin-transfer-molding* (VARTM) e.g. Hardcore Composites, *open mold hand lay-up* e.g. Kansas Structural Composites). Each has its own merits. The following table is offered as a qualitative comparison:

➡feature manufacturing method	ability to get custom sizes	adherence to dimensional tolerances	attractive cost	ability to incorporate special features e.g. scuppers	overall quality
1. Pultruded	L	H	L	L	H
2. VARTM	H	L	H	H	M
3. Open mold	H	M	H	M	M

relative benefit: H = high, M = Medium, L = Low

STRUCTURES DESIGN ADVISORY CODE: 02-003	DATE: Dec. 9, 2002	PAGE: 5
SUBJECT: FRP Decks & Superstructures		

If an FRP deck is used a special specification will need to be prepared. Assistance is available from the contacts listed in this Design Advisory. The specification will be performance based because the systems use proprietary designs and manufacturing methods. Using performance standards also has additional benefits of encouraging innovation and refinement of new technology.

III. DESIGNER GUIDELINES:

FRP deck systems are required to meet a performance based specification. They are required to have PE certified design calculations, an installation procedure and working drawings are required to be submitted to the Deputy Chief Engineer (Structures). Wearing surface materials are also to be selected from an Approved List if not listed specifically as part of the decking system. Assistance in selecting an appropriate wearing surface is available from the contacts listed at the end of this Design Advisory. Each supplier is responsible for certification of the finished product as well as quality control (QC) during the manufacturing process. NYSDOT will verify adherence to the approved QC plan through its own quality assurance (QA) reviews. Criteria for placing FRP decks and superstructures on the Department's Approved List of Materials and Equipment is currently being developed.

Though FRP decks and superstructures are very similar in nature, one important distinction is that an FRP deck is a manufactured product that the supplier designs and manufactures according to stipulated parameters. The manufacturer must certify compliance. An FRP superstructure with a span over 20' is, however, by definition, a bridge. NYS law requires that any bridge, either site built or manufactured, be certified by a licensed NYS professional engineer and that a Level 1 load rating be filed with the Department.

Though not mandatory, the project designer should consider specifying that FRP superstructures be load tested prior to placing the bridge in service. This will serve to verify the Finite Element Model.

Project designers may consider FRP decks in the following circumstances:

1. A posted bridge that could benefit from a reduction in dead load and subsequent increase in load rating.
2. Where a bridge needs to be widened without imposing additional loads on the substructure.
3. An historic structure that must be saved (i.e. rehabilitated instead of replaced) due to its cultural value.
4. Moveable spans where the light weight can save operating expenses.
5. A bridge with an existing light weight deck (e.g. steel grating) that needs another lightweight deck. An FRP deck provides the additional benefit of protecting the superstructure from the elements.

STRUCTURES DESIGN ADVISORY CODE: 02-003	DATE: Dec. 9, 2002	PAGE: 6
SUBJECT: FRP Decks & Superstructures		

6. Any bridge needing a deck designed for light duty like those on locally owned structures constructed of timber or corrugated steel pans with asphalt. In these instances, stringer spacing is typically less than three feet.
7. When there is a benefit to installing decks or superstructures in a short time period to reduce the cost of maintenance and protection of traffic and reduce congestion.

Other project selection criteria:

1. Traffic volume: Though fatigue test data suggests that there is not a concern about using of FRP decks on high volume roads, the project designer should be cautious about the application in an area that would be difficult to monitor or repair. Low volume roads provide an opportunity for easy access so that more can be learned with little risk.
2. Skew: Deck manufacturers have been successful in the fabrication and installation of skewed superstructures and the use of FRP decks on skewed steel bridges, however the pultruded deck systems are more difficult to adopt to a skew.
3. Span: There are several deck systems that can be used with a span length up to 2.5m. Superstructures built thus far have been relatively short spans (<14m). This is due to the difficulty in controlling deflection. Longer spans will most likely require the use of high performance carbon fiber or a hybrid system which utilizes concrete or other materials with FRP.
4. Depth: FRP decks are commonly available as 200mm (8") or 125 mm (5") deep section, although custom depths are available. During preliminary project design, a rule of thumb can be used for the depth of a FRP superstructure: i.e. one inch for each foot of span. If desired, a slimmer section can be obtained by asking the manufacturer to engineer the fabric architecture accordingly.

Cost Considerations:

In certain circumstances FRP decks and superstructures can offer significant advantages that result in a project with net savings over one using conventional construction practice. For example, capitalizing on their modular nature FRP decks can reduce the duration of a project and subsequent user costs. At the present time, complete FRP superstructures are generally very expensive compared to precast concrete structures in the same span range. Precast concrete structures offer many of the advantages of FRP superstructures. For this reason, the use of complete FRP superstructures is not strongly recommended at this time.

Since the cost of an FRP deck or superstructure typically is substantially more than steel and concrete, part of the scoping process must involve an evaluation of all costs

STRUCTURES DESIGN ADVISORY CODE: 02-003	DATE: Dec. 9, 2002	PAGE: 7
SUBJECT: FRP Decks & Superstructures		

associated with a project. FRP may offer direct monetary and user cost savings due to speed of construction, shortening of the project, elimination of a detour structure, etc. Similar benefits may also be available from prestressed concrete systems, precast structures, exodermic decks, etc. A cost comparison should be made considering all

available options. Since cost can be influenced by a supplier's schedule and product demand, manufacturers should be contacted for an estimate of current prices. Recent price ranges including installation are:

- Decks: \$700 - \$860 /SM (\$65-\$80 /SF) of deck area
- Superstructure: \$1,600 - \$2,125/SM (\$150 - \$200 /SF) of deck area

Specific design criteria are:

1. To avoid long term creep, predicted strains under design dead load shall be less than 10% of the FRP composite's minimum guaranteed ultimate strength. Strain under all service loads shall be less than 20% of the minimum guaranteed ultimate strength. The ultimate strength is based on coupon testing and noted in the approved plans.
2. An environmental durability factor (knockdown factor) of 0.65 is applied to the material properties to account for degradation of properties over time.
3. Because of the material's typical low modulus of elasticity, most designs will be driven by deflection limitations and not strength requirements.
4. Although the criteria for deflection is somewhat arbitrary, it should typically be kept at L/800 of the supporting span length for superstructures and L/500 for decks.
5. In cases where the deck is expected to fail in a manner other than tension of the laminate, a factor of safety of five shall be applied. We anticipate that, as reliability factors are obtained for FRP materials, a load and resistance factor design (LRFD) methodology will be developed by AASHTO.
6. Protect exposed surfaces from ultraviolet (UV) exposure using suitable paint.
7. If an FRP deck is being installed on a steel superstructure, careful consideration must be given to the method of attachment. Composite action between the FRP and steel is not to be assumed in capacity calculations. However, the connection itself must be detailed to prevent failure when load is transferred between the two. The design of the interface should either insure composite action or provide a slip mechanism to prevent it.
8. FRP can heat up rapidly when exposed to direct sunlight. A dark wearing surface exacerbates the phenomenon. Experience has shown that a thermal gradient will occur between the top and bottom of an FRP deck when surface temperatures change fast but are not able to be conducted through the FRP immediately. This problem is especially likely to occur in early spring or late fall. The design shall assume a 100 degree F temperature difference between the

STRUCTURES DESIGN ADVISORY CODE: 02-003	DATE: Dec. 9, 2002	PAGE: 8
SUBJECT: FRP Decks & Superstructures		

top and bottom of the deck and account for any subsequent internal thermal stresses. Since this temperature gradient can lead to an arching action as the top surface expands faster than the bottom, it may also affect the selection of bearing and anchorage details.

9. Each manufacturing method has its own benefits. In general, pultruded sections produce a good quality, consistent product with tight dimensional tolerances; however, prices tend to be slightly higher than for other methods. The more custom methods (VARTM and hand lay-up) allow the depth of the section to be easily changed, and to accommodate a cross slope, inclusion of scuppers, or custom "knockouts." The designer needs to decide if the application necessitates a particular method of fabrication.
10. Acceptable wearing surfaces will be designated for each particular manufacturer.
11. A bonded FRP curb may be used if and only if it is protected from impact by bridge rail. Concrete curbs have also been attached to FRP decks.
12. The joint over the bridge seat can be eliminated by carrying the FRP deck over the abutment stem to terminate on the approach side of the bridge. This allows any joint leakage to weep into the fill rather than onto the seat.
13. Pourable silicone joint material has performed well as an expansion joint and is easily repairable.

The project designer will need to show outside limits of the deck, (the core of the system will be as per approved shop drawings), maximum deck thickness and weight, abutment and bearing details with elevations, and final elevation of the deck surface with wearing surface. Railing treatment will also be detailed by the project designer.

Since FRP decks are relatively new, consultation and approval of the Main Office Structures Division DCES is required for all proposed installations. This should be done as early as possible in the design process.

Questions shall be directed to Michael Twiss at (518) 485-7256 or Art Yannotti at (518) 457-4453 of the Structures Design Bureau.